Challenges for Middleware Imposed by the Tactical Army Communications Environment

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Revolution in Battlefield Command and Control

‘Network-Centric Warfare’

- ‘An information-superiority enabled concept of operations that generates increased combat power by networking sensors, decision makers and shooters to achieve:
  - shared awareness
  - increased speed of command
  - higher tempo of operations
  - greater lethality
  - increased survivability
  - a degree of self-synchronization

D.S. Alberts, J.J. Garstka, F.P. Stein, ‘Network centric warfare: developing and leveraging information superiority’, CCRP Publication Series, 1999

Revolution in Battlefield Command and Control

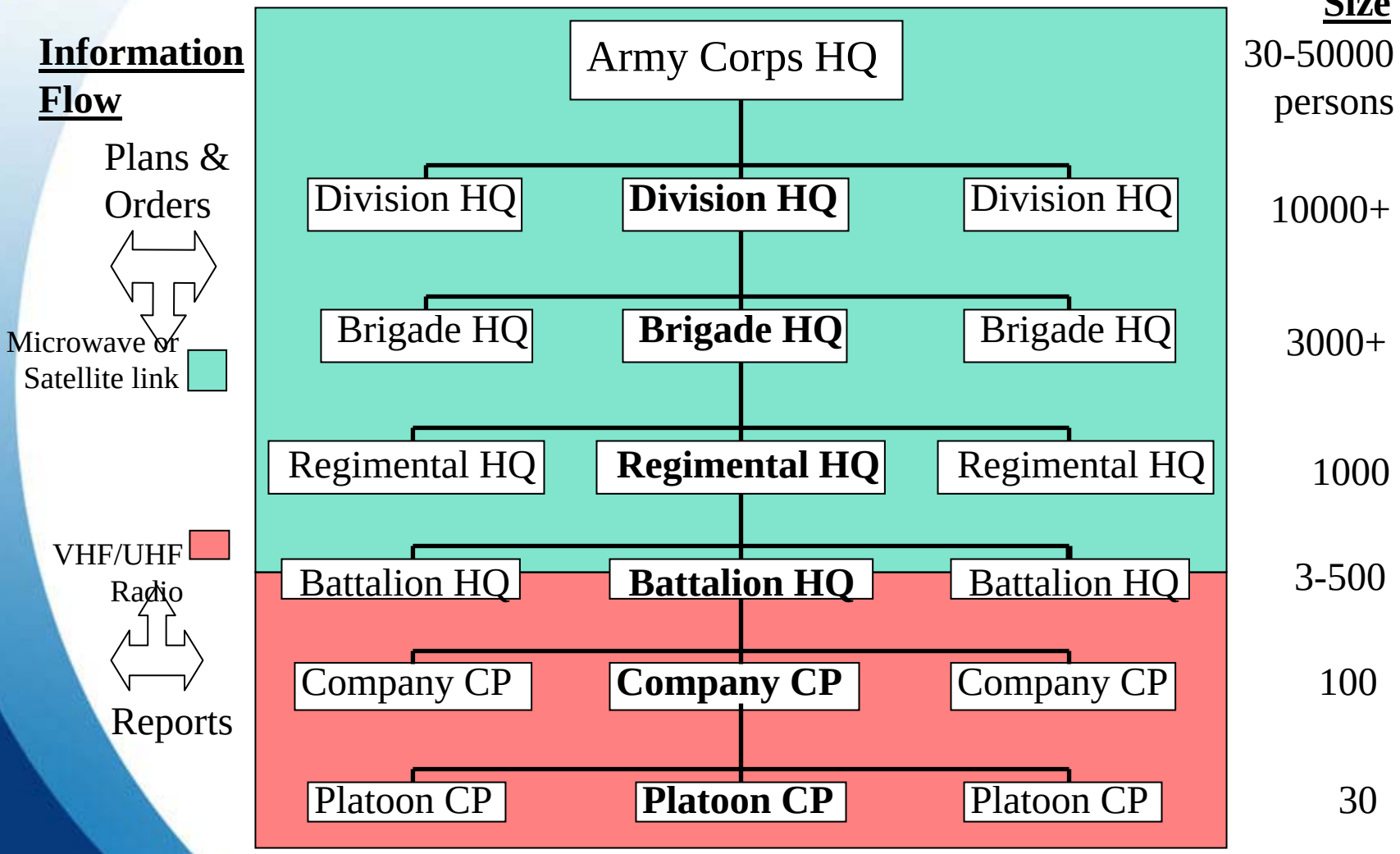
- Introduction of digital C3I systems
- Promise of increased battlefield awareness
- Need to distribute digital data
  - quickly
  - widely
  - reliably
- ‘The right information to the right place at the right time’

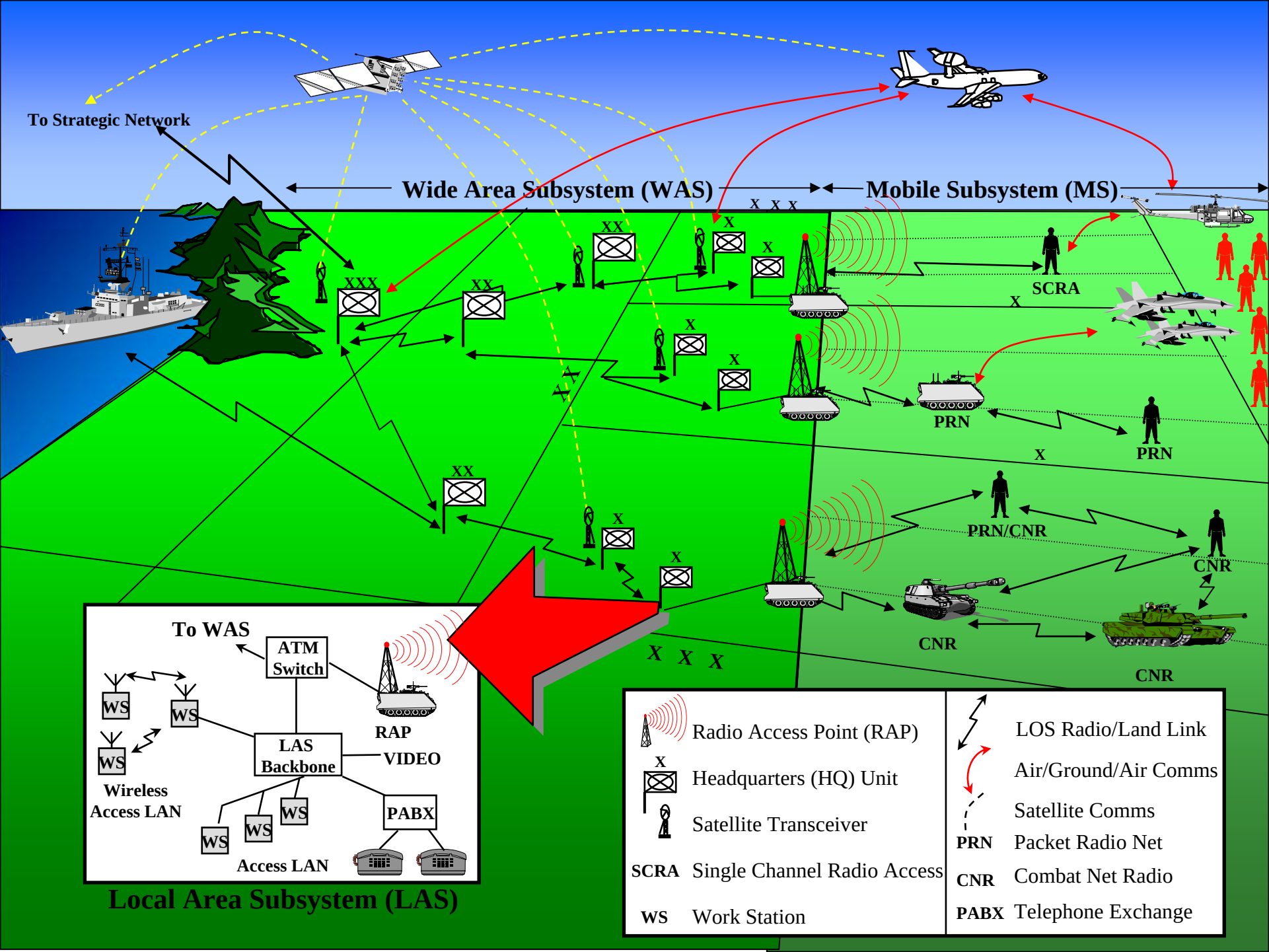
Outline of Presentation

- Army command and control structure
- The tactical communications environment
- Challenges posed by the tactical communications environment

Army Command and Control Structure

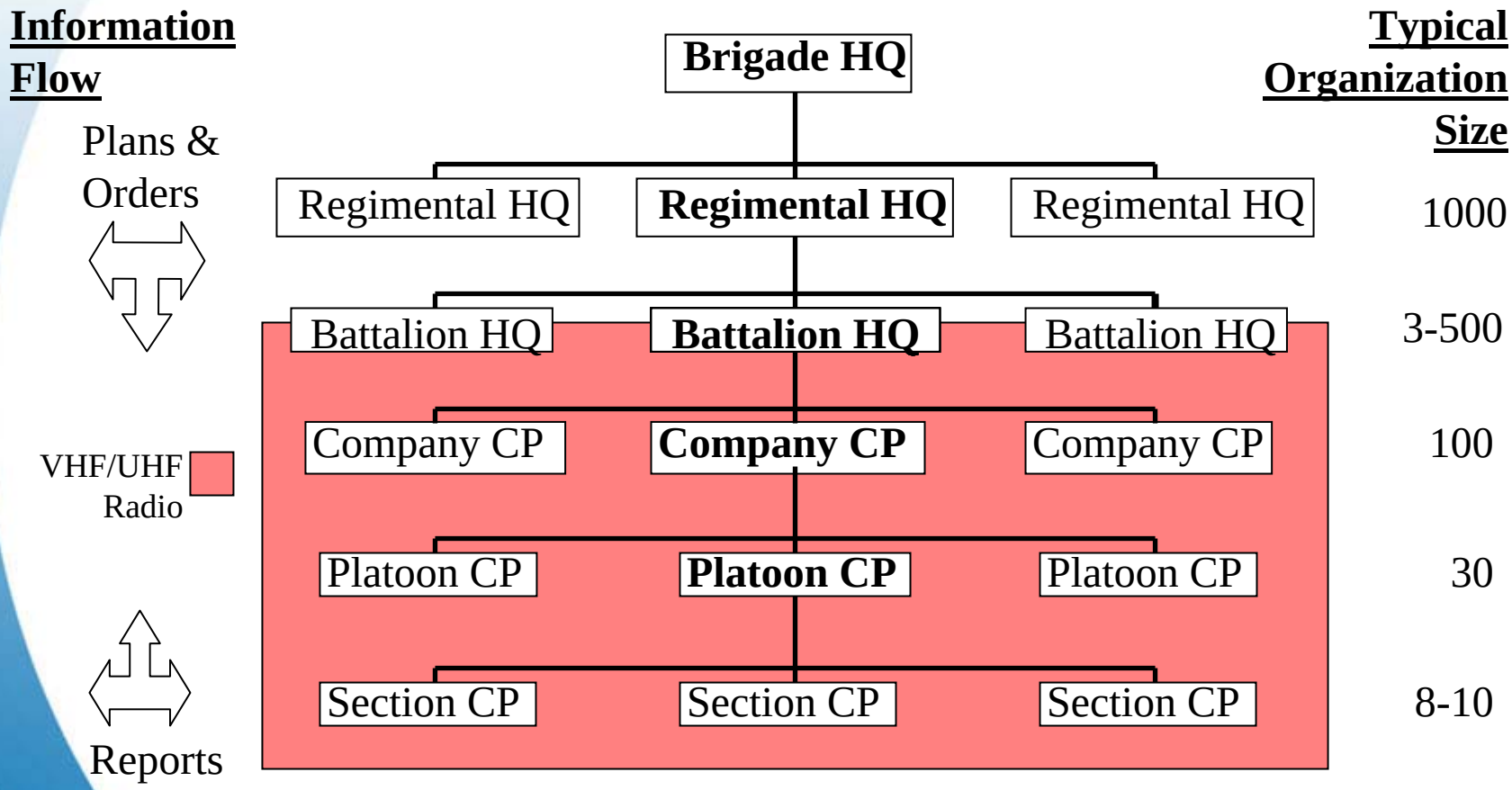
Army Command and Control Structure



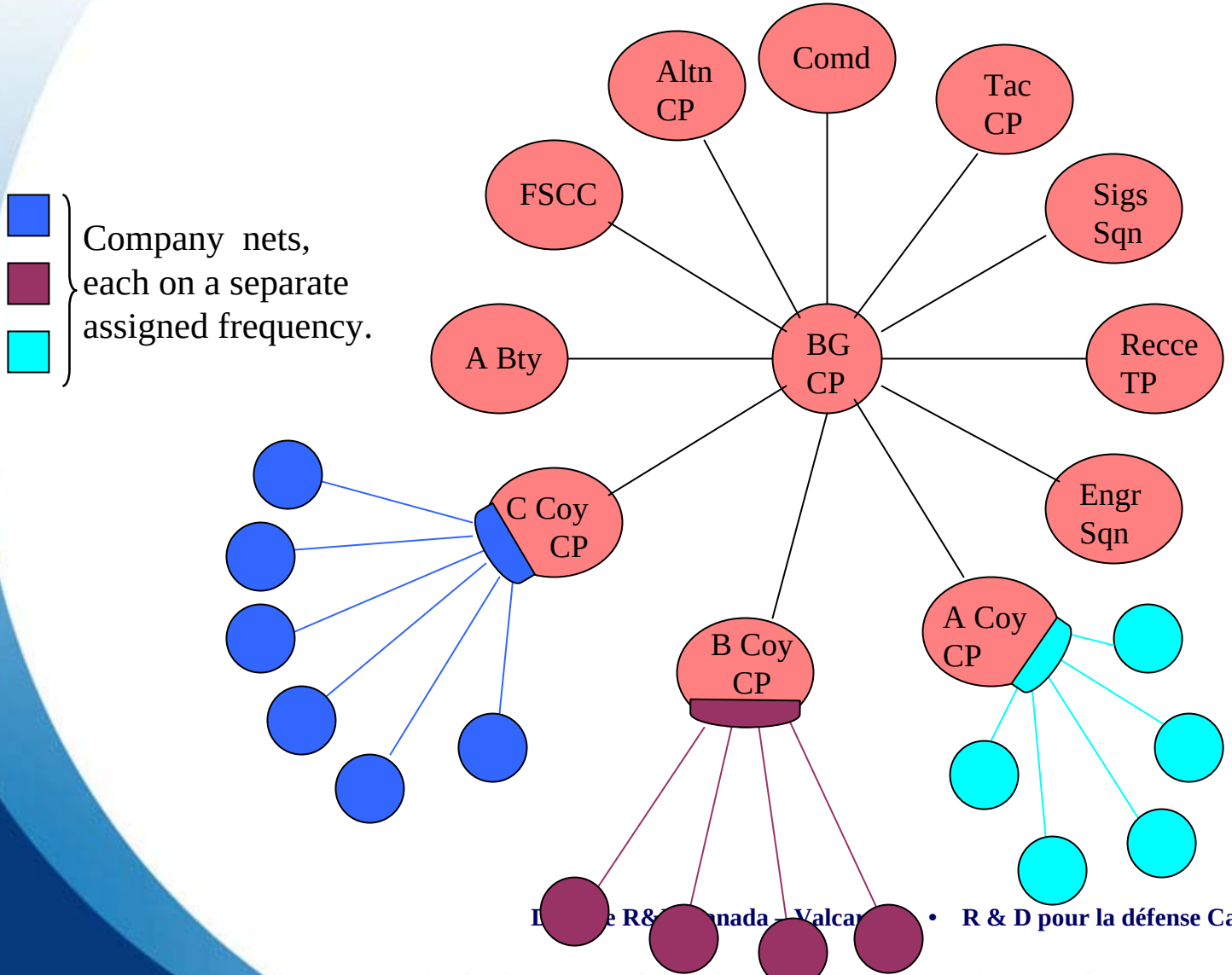

To Strategic Network
Wide Area Subsystem (WAS)
Mobile Subsystem (MS)
SCRA
PRN
PRN
PRN/CNR
CNR
CNR
CNR
To WAS
ATM Switch
RAP
VIDEO
LAS Backbone
WS
WS
WS
Wireless Access LAN
WS
WS
WS
PABX
Access LAN
Local Area Subsystem (LAS)
Radio Access Point (RAP)
Headquarters (HQ) Unit
Satellite Transceiver
SCRA Single Channel Radio Access
WS Work Station
LOS Radio/Land Link
Air/Ground/Air Comms
Satellite Comms
PRN Packet Radio Net
CNR Combat Net Radio
PABX Telephone Exchange

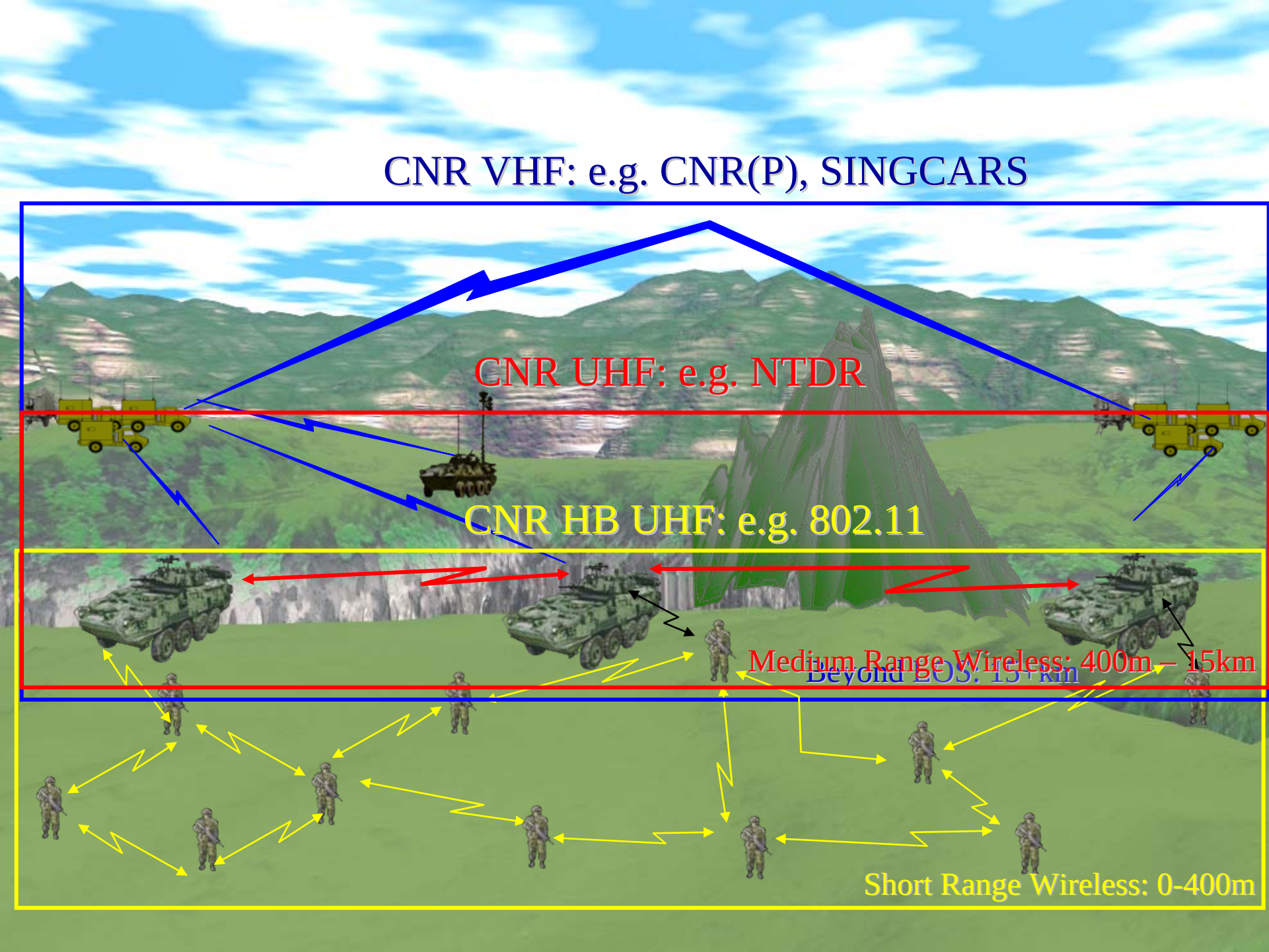
The Tactical Communications Environment

Army C2 Structure -Tactical Domain



Notional Battle Group (augmented Battalion) Command Net




CNR VHF: e.g. CNR(P), SINGCARS
CNR UHF: e.g. NTDR
CNR HB UHF: e.g. 802.11
Medium Range Wireless: 400m – 15km
Beyond LOS: 15+km
Short Range Wireless: 0-400m

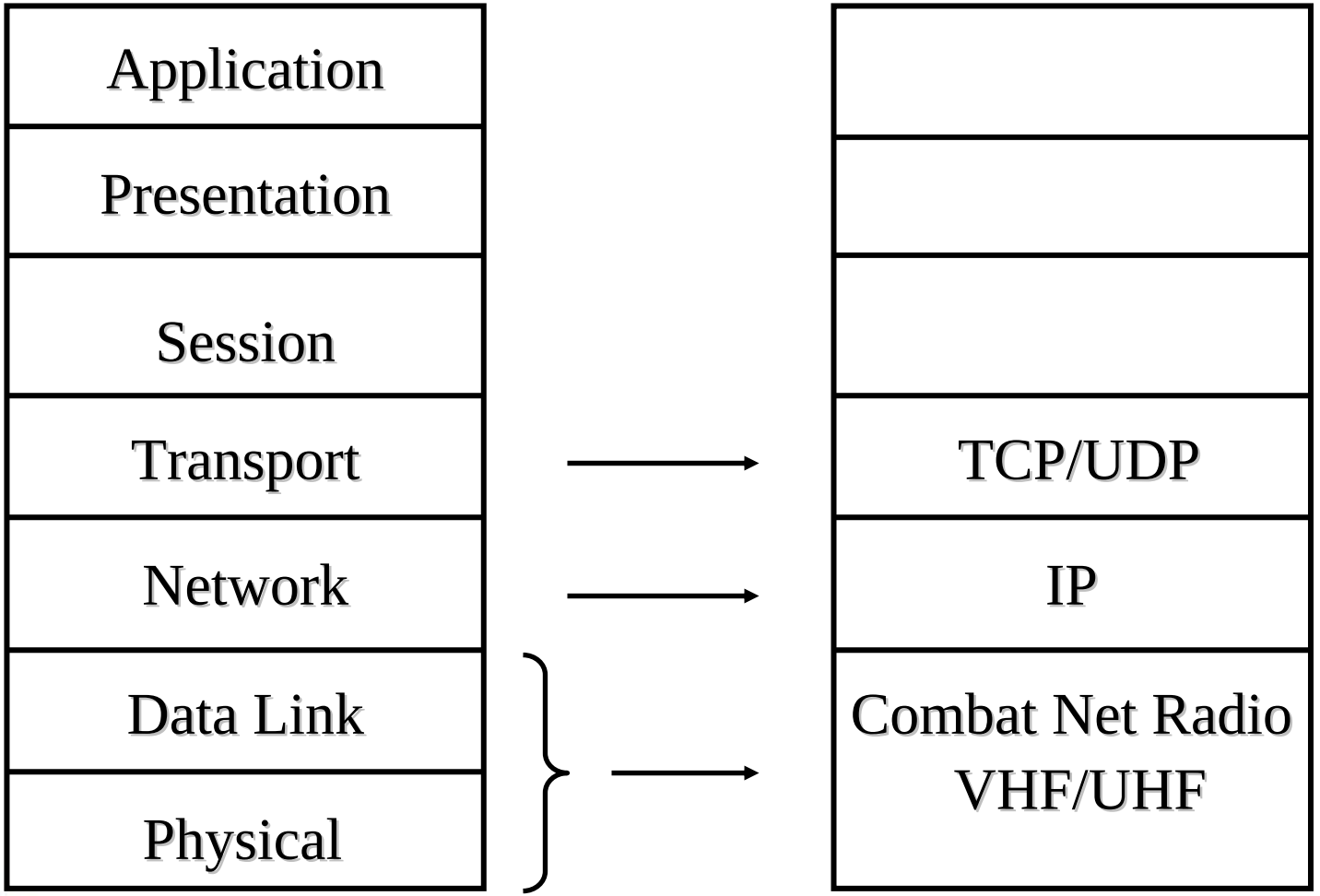
CNR Domain

•VHF: Vast majority of radios capable of 16kbps half duplex.

•UHF: Radios capable of 288kbps full duplex.

•High Band UHF: (e.g. 802.11) capable of 11 Mbps.

Network Layers



CNR – VHF (Canadian Example)

- Reality: usable throughput at the application layer is a fraction of the base rate:

  CNR(P) – Max throughput on DATA ONLY network: ~ 1kbps

  SHARED AMONGST USERS

  → 25 radios/net = 40 bps/user

- Reality: residual BER as low as 10^{-5}
- Other VHF CNR radios have similar performance

CNR UHF (225 – 450 MHz)

- Near Term Data Radio (NTDR)
  - 288 kbps is for ‘well situated’ sites
- Reality: true tactical environment performance is approximately:
  - ~16kbps from 22kbps link; and
  - ~80kbps using a 100 kbps link;
- Available throughput is still shared amongst users (80kbps/25 = 3.2 kbps)
- Error conditions similar to VHF

Transfer Control Protocol (TCP)

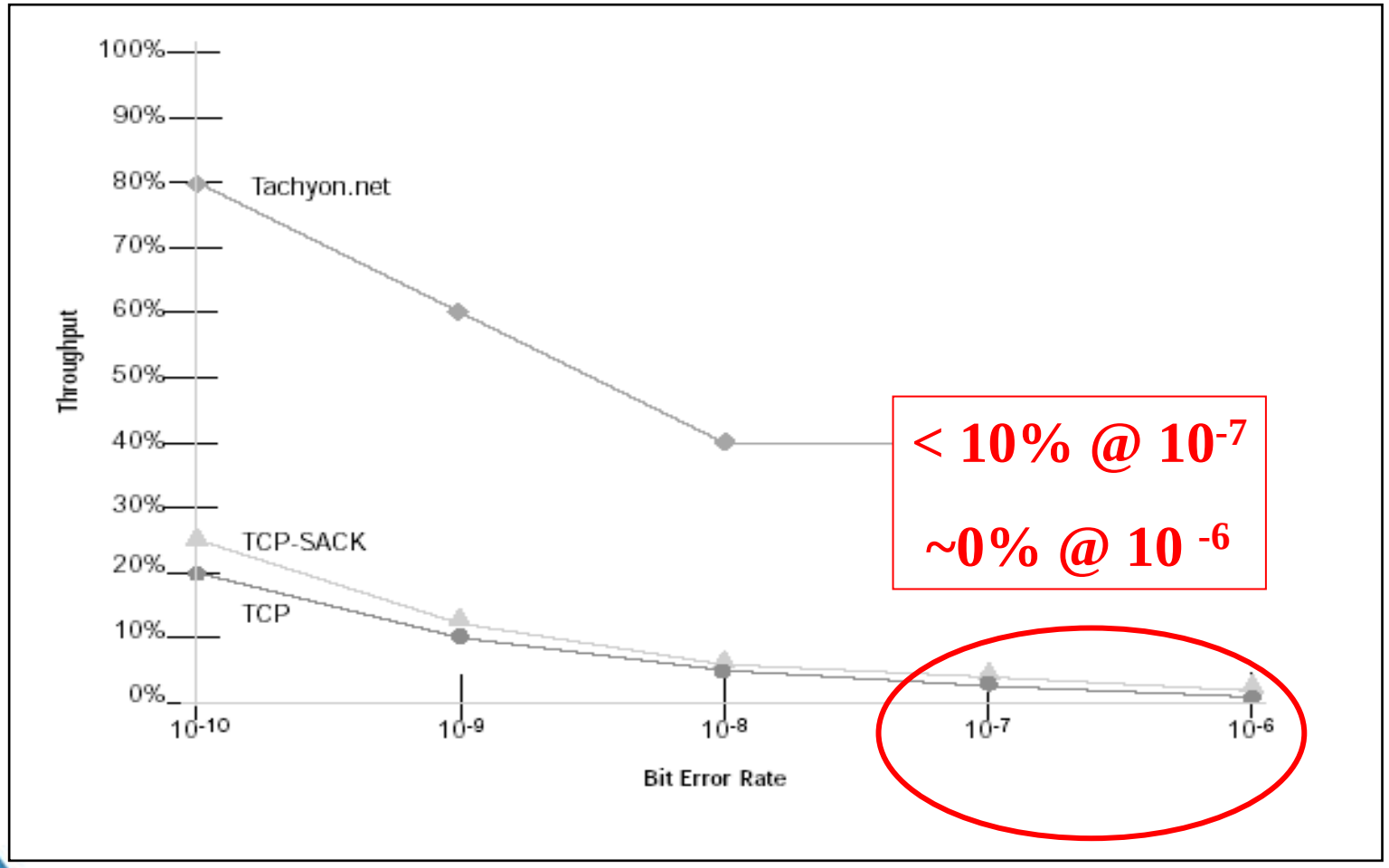
- TCP was designed for wired networks:
  - All controls designed for congestion, not errors
  - TCP is very sensitive to Bit Error Rate (BER) and Latency
  - Error in wireless domain trigger TCP congestion controls (e.g. 1 packet lost = 50% cut in tx rate)
  - TCP is connection-oriented → in wireless tactical domain (high BER, latency, long fades) TCP connections timeout regularly

TCP

- As a consequence…

  Standard TCP is non-functional in most tactical wireless environments !!

TCP and Bit Error Rate



Challenges Posed by the Tactical Communications Environment

Network Topology on the Tactical Battlefield

- Unreliable broadcast medium (radio) provides comms links
- Highly mobile entities participate as nodes on C2 network
- Network of sub-networks; each sub-net on different base frequency
- Nodes frequently connect/disconnect from subnetworks
- A single radio can participate on only one sub-net at a time.
  - participation on multiple nets requires multiple radios
- Number of radios in vehicle restricted by space limitations

Connectivity

- Planned loss of connectivity due to:
  - re-assignment of role for node
  - need to participate on multiple networks with single radio by switching frequencies
- Unplanned loss of connectivity due to:
  - terrain or atmospheric interference
  - nodal separation exceeding radio range
  - enemy jamming
  - damage due to enemy action
  - equipment malfunction

Tactical Communications Constraints

- Units are highly mobile
- Communicate by radio (voice and data; voice only; data only)
- Low data throughput (< 1 kbit/second for CNR(P))
- Variable data throughput
  - highly dependent upon traffic load on communications network
- Unreliable links (frequent disconnection, high bit error rates)

Data Distribution Requirements in Tactical Wireless Domain

- Autonomous cooperating nodes
  - disconnected operation
- Peer-to-peer model (not client-server)
  - avoid single point of failure
- Propagate updates asynchronously on ‘all-informed’ basis
  - profit from (shared) broadcast medium
  - change role without substantial one-time data transfer
  - recover data from any node
- Data recovery must be carefully managed (bandwidth issue)
- Data ownership an important issue (integrity and bandwidth)
  - single ownership of data to avoid/minimize data conflicts
- Negative acknowledgement scheme

The challenge – how to communicate and share information effectively in this highly constrained communication environment ?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